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PERFORMANCE OF ASYMMETRIC BUILDING STRUCTURE WITH BASE ISOLATOR USING PUSHOVER ANALYSIS

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ABSTRACT

The idea of earthquake resistant buildings concept is not designed by strengthening their structural resistance to earthquake forces, but rather how to reduce earthquake forces acting on the building. The structural system that is able to reduce earthquake forces is known as base isolation. The building will receive a lateral force due to earthquake, then in asymmetrical buildings, the lateral force will work very large in the meeting area of two fields; it is expected that the building can withstand the earthquake force without significant damage to the structure. The purpose of this study is to evaluate the comparison of reinforced concrete building performance using base isolator as an alternative to reducing earthquake loads. The structure of the building to be planned consists of 2 conditions, namely the structure of Special Moment Resisting Frame Structure (SRPMK) type of fixed base and base isolator. The use of base isolator is done by varying the design deformation value (γ) of 1.0; 1.5; 2.0; and 2.5 applied to the building plan. The base isolator used is High Dumper Rubber Bearing (HDRB). The building to be analyzed is a 10-story asymmetrical reinforced concrete building (L-Shape), located on a medium land located in Banda Ace hand functioning for offices. The analytical method used is pushover analysis with SAP 2000 assistance program. The results show an increase in the natural period of isolated base structures compared to fixed base structures reaching an average of 2,030 times. Inter-story drifts on isolated base structures are smaller than fixed base structures in both x and y axis. The use of base isolator can reduce base shear in the x and y axis of buildings reaching an average of 32.84% and 32.19%. Evaluation of structure performance according to FEMA-356 and ATC-40 is at the level of Damage Control (DC) performance.

KEYWORDS: Building Structure, Resisting Frame Structure & High Dumper Rubber Bearing (HDRB)

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Original Article

1. INTRODUCTION

When an earthquake occurs, the building will receive lateral force. In the asymmetrical building the lateral force that works in the meeting area of the two fields will work very large. It is expected that the building can withstand the earthquake force to a certain stage without significant damage to the structure.

Along with the development of construction technology, new concepts emerge about earthquake resistant buildings. The idea of this concept is that earthquake-resistant buildings are not designed by strengthening their structural resistance to earthquake forces but rather how to reduce earthquake forces acting on the building or add a structural system that is specifically designed to absorb some of the earthquake energy that enters the building and only as small (the rest) which will be borne by the building structure components. This structural system that is able to reduce earthquake forces is known as base isolator or seismic isolation (Erista D, 2011). The purpose of this study is to evaluate the performance of Special Moment Resisting Frame Structure (SRPMK) asymmetric building structures with *fixed base* and Special Moment Resisting Frame Structure (SRPMK) asymmetric building structures with base isolator type *High Dumping Rubber Bearing* (HDRB).

2. LITERATURE REVIEW

2.1 Performance Based Design

According to Dewobroto (2006), the concept of performance-based planning is a combination of retaining aspects and service aspects, so that the structure's ability to accept earthquake loads (capacity) and the magnitude of earthquake loads received by the structure (demand). Therefore, an earthquake-resistant and economic structure can be planned.

Referring to FEMA (Federal Emergency Management Agency) -356 (1997) which becomes the classic reference for performance-based planning, the category of structure performance level is, Immediate Use (IO = Immediate Occupancy), Occupational Safety Guaranteed (LS = Life-Safety), Avoid total collapse (CP = *Collapse Prevention*). A quantitative description of FEMA-356 performance levels can be seen in figure 1 below.

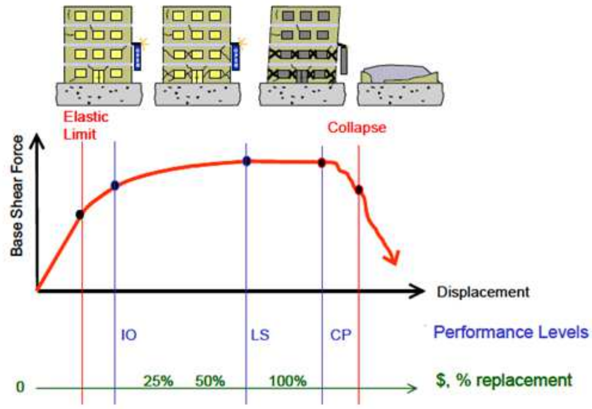

Figure 1: Illustration of Earthquake Based Engineering Performance (ATC 58) Dewobroto (2006).

While the level of structure performance regulated in ATC − 40 (*Applied Technology Council-40*) is as in Table 1 below.

Table 1: Level of Structure Performance According to ATC−40

Inter-story drift limit	Immediate Occupancy	Damage Control	Life safety	Structural Stability
Maximum Total Drift	0.01	0.01-0.02	0.02	0.33 V_i/P_i
Maximum Inelastis Drift	0.005	0.005-0.015	No Limit	No Limit

Source: ATC−40

2.2 The Concept of Nonlinear Static Analysis Method (Pushover)

Wiyono and Yuwono (2008) stated that static analysis of nonlinear pushover (pushover analysis) is a way to determine the performance of a structure. The basic concept of pushover analysis is to add a certain static lateral load pattern in a direction that is gradually increased. This addition of static lateral load is stopped until the structure reaches a certain displacement target or load (performance point) or when the structure reaches a collapse condition. Pushover analysis is performed after linear structure analysis and structure design has been completed.

2.3 Base Isolation System

The ideas behind the concept of base isolation are very simple, namely how to separate the building base embedded in the land and the upper building structure, so that the movement of the soil is not directly transferred to the upper structure

(Naeim and Kelly, 1999).

2.4 High Dumping Rubber Bearing (HDRB)

According to Teruna (2005), the main principle of the workings of base type elastomeric bearing isolators (HDRB or LRB) is to extend the natural vibrational time of structures outside the earthquake's dominant frequency to 2.5 or 3 times the vibration time of structures without insulators (fixed base structures) and have damping between 10% to 20%. As a result, the earthquake force distributed to the structure becomes smaller.

The horizontal parameter values of HDRB are shown in figure 2. The *equivalent lateral stiffness value* (Keq) and the *damping equivalent value* (Heq) are two important parameters used for the initial trial of lateral seismic isolation deformation requirements using the static equivalent method. This value is used in the *static equivalent* analysis to simplify the nonlinear response of HDRB.

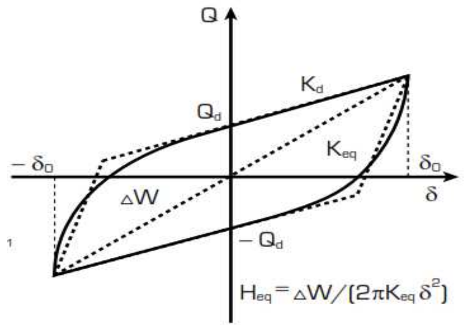

Figure 2: Horizontal Parameter Values from HDRB.

Source: Bridgestone Set of Catalogues in seismic isolators (2017)

3. RESEARCH METHOD

3.1 Building Planning

The construction of the building to be planned is a 10-story SRPMK reinforced concrete building with a height of 4 m each. Structural modelling will be carried out on two conditions, namely, the SRPMK *fixed base* building and the SRPMK building with *base isolators*. The function of the building is for offices (I = 1), which is assumed to be located in the city of Banda Aceh, with a distance from the beach is 3.12 km and based on the soil investigation Logbor data, it is found that the depth of the sub grade is located at a depth of 6 m with an NSPT value> 50, from soil data at these locations can be categorized as land with elementary school site (medium land).

Structural modelling that will be carried out in this research is the *L-Shape* Building. Building models are included in the classification of irregular buildings; the length of each span of X and Y is 4 meters, with the height of each building the same floor that is 4 m. The quality of concrete used is fc '= 30 MPa. Steel quality fy = 400 MPa, fys = 240 MPa. The plates use 120 mm and 100 mm thickness for the slab, with dead load (SDL) for the floor plate 10.8 kN / m^2, live plate load of 2.4 kN / m^2 (floor) and 0.96 kN / m^2 (roof).

The dimensions and size of the cross section are as follows:

- Columnf. 1-5 : 60×60 cm, f. 6-10 : 50×50 cm
- Main beam: 25×50 cm

Structure Model in this research is:

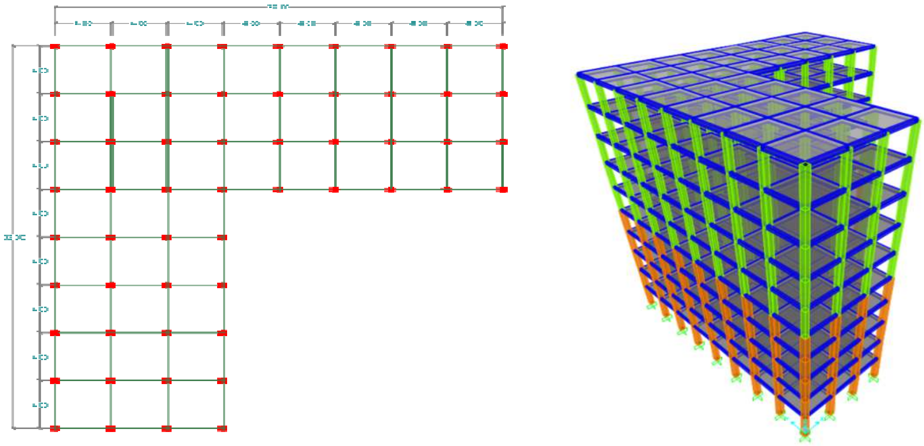

Figure 3: 3D Plan and Structure Model.

Planning standards that are used by following SNI 1727: 2013 are as a basis for determining the minimum load for building design, SNI 2847: 2013 concerning Structural Concrete Requirements for Building Buildings and SNI 1726: 2012 concerning Procedures for Planning Earthquake Resilience for Building Structures and Non-Buildings. Analysis and modelling of building structures is carried out with the help of SAP2000 software. Building structure modelling is carried out with the SAP2000 v.20 program.

The addition of HDRB isolator *base parameters* was done by varying the design deformation value (g), the value (γ) used is 1.0; 1.5; 2.0 and 2.5. This value (γ) will affect the design value of HDRB, namely *Equivalent shear stiffness*(equivalent lateral stiffness) Keq, *equivalent damping ratio* Heq, *initial stiffness* K1, *post yield stiffness* K2, *characteristic strength* (QD), and Functions that provide the ratio of characteristic strength to maximum shear force U. The following are variations in the design property values according to the value γ:

Table 2: Structure Modelling Simulation

No	γ	A mm^2	n	tr (mm)	H mm	G eq N/mm^2	H eq	U N/mm^2	K_{eq} 10^3 KN/m	K_2 10^3 KN/m	K_1 10^3 KN/m	Q_d KN
1	1	441600	40	5.0	200	0.620	0.240	0.408	1.370	0.811	8.113	111.638
2	1.5					0.515	0.231	0.405	1.138	0.677	6.775	138.157
3	2					0.475	0.216	0.403	1.048	0.625	6.253	168.983
4	2.5					0.469	0.200	0.403	1.036	0.619	6.186	208.767

4. RESULTS

4.1 Result

4.1.1 Period of Structure Natural Vibration

Results of analysis show that the value of g on the base isolated building is greater than the fixed base structure. It proves that base isolators are effective to extend structure period of the building. Figure 2 shows the comparison of vibration period.

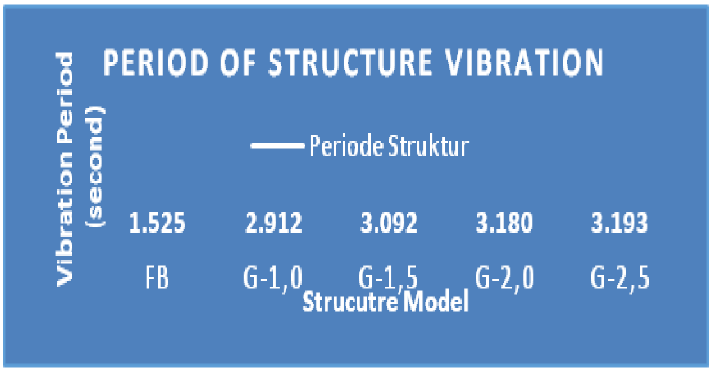

Figure 4: Period of Structure Vibration.

4.1.2 Inter-Story Drift

Based on figure 4 and 5, inter-story drift values of the 1st and 2nd floor on the isolated base structure are greater than the values of fixed base structure. While on the 5th to 10th floor, the inter-story drift values are smaller than those of fixed base structure. This is influenced by base displacement of the structure due to application of base isolators. The inter-story drift value of isolated base building is closer to zero than that of fixed base structure. The maximum inter-story drift occurs on the 3rd floor of the fixed base structure and the 1st floor of the isolated base structure.

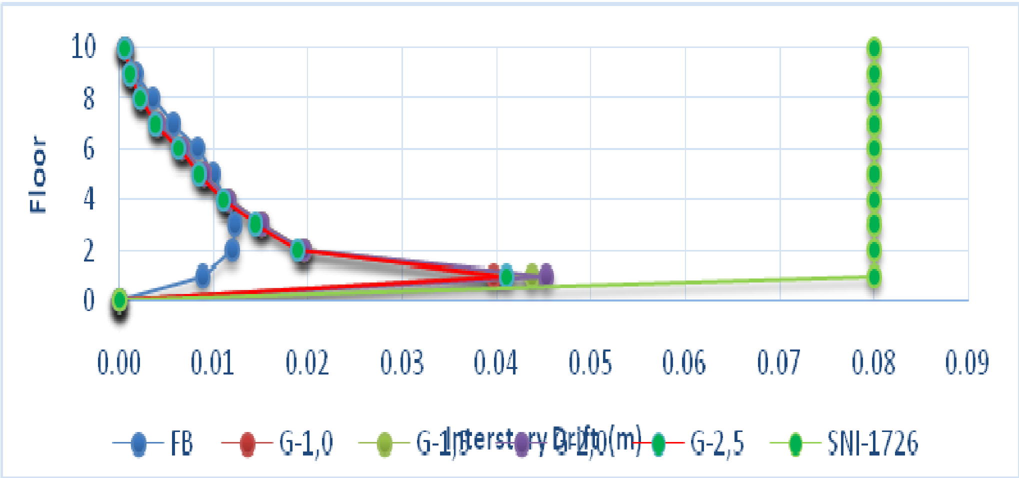

Figure 5: Graph of Inter-story Drift Comparison of Fixed Base with HDRB X Axis.

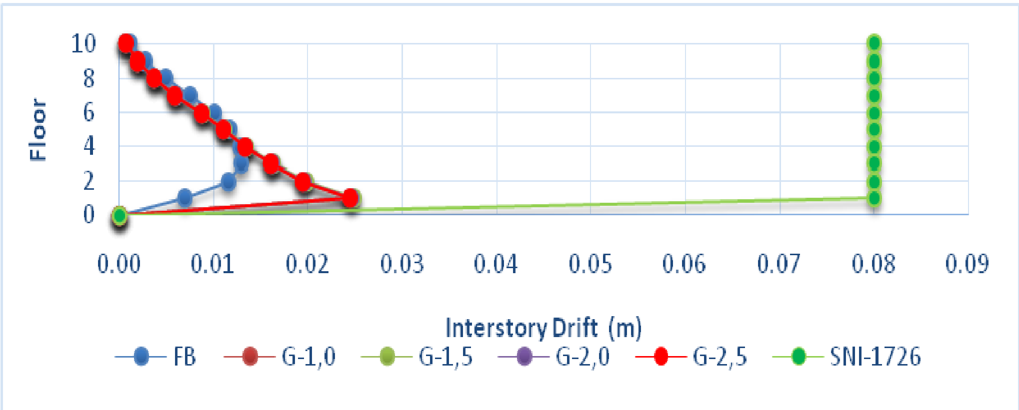

Figure 6: Graph of Inter-story Drift Comparison of Fixed Base with HDRB Y Axis.

4.1.3 Structural Performance Evaluation Based on Capacity Spectrum Method

Table 1 shows ATC-40 based performance evaluation on the maximum inter-story drift values. The maximum inter-story drift values of axis X and Y in both fixed and isolated base structures can be seen in Table 3. Referring to ATC-40 method, the maximum inter-story drift values of both fixed and isolated base structure for x and y axis is smaller than 0.01 m. Therefore, performance of the structure is at Immediate Occupancy level.

4.2 Discussions

4.2.1 Structure Period

Based on the research results, as shown in figure 3, application of base isolator is effective to extend the period of building structure. The period of fixed base structure is 1,525 seconds; while the shear strain value of base isolated structure is varied from 1.0; 1.5; 2.0 to 2.5. The structure period increases along with the change in value (γ), the period of vibration on fixed base structure to type 1 base isolator structure with a value of γ = 1,0 (GB-1,0) increases by 1.910 times; while for GB-1.5; GB-2.0; and GB-1.0 are 2.028; 2,086 and 2,094 times respectively. Increase in structure period causes smaller inter-story drift and earthquake forces of the building.

4.2.2 Inter-story Drift

Based on ATC-40 and FEMA-356 methods, the Inter-story Drift values on the base isolated structure for axis x and y as a whole are smaller than the fixed base structure. Due to base isolator application, the earthquake force on the structure will first affect the base isolator, then passed on to the upper structure. It proves that isolator reduces the inter-story drift.

4.2.3 Structure Performance Evaluation Results

Structure performance is evaluated based on the maximum value of structure drift when it reaches the performance point. Comparison of performance points for each structural model can be seen in table 3.

Table 3. Performance Level of Fixed Base and Base Isolator Structures Based on ATC-40

Structure Model		γ	ATC-40 Maximum Inter-story Drift (m)		Structure Performance Criteria
			Axis *x*	Axis *y*	
Fixed Base	FB	-	0.012	0.013	Damage Control
Base Isolated	G-1,0	1.0	0.040	0.025	
	G-1,5	1.5	0.044	0.025	
	G-2,0	2.0	0.045	0.025	
	G-2,5	2,5	0.041	0.025	

Refers to ATC-40 method, the maximum inter-story drift values of both fixed and isolated base structure for x and y axis are smaller than 0.01 m, therefore the structure performance is at Damage Control level. The level shows that this structure requires few or no repairs after earthquake.

5. CONCLUSIONS

- Application of base isolators on building structures can increase natural period of the structure. The natural period of structure with base isolator is increased by 2,030 times compared to fixed base structure.
- Inter-story drift on structure with base isolators is smaller than fixed base structures in both x and y axis. This results in smaller earthquake (lateral) force on the structure.

- Application of isolators on a building increases lateral displacement on the ground floor but minimizes the inter-story drift, thus making the building move as a rigid structural entity when earthquake strikes.
- Evaluation has made based on maximum inter-story drift. The maximum inter-story drift of fixed base and isolated base structures for x and y axis are at 0.01 m and 0.02 respectively, thus the structure performance is at Damage Control level.

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